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A Multivariate Analysis of Morphometric and Exosomatic Characters of Iguanid Lizards of the Patagonian *Liolaemus kingi* Complex

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For more than a century *Liolaemus kingi* (Bell, 1843) has been reported as a classical viviparous Patagonian iguanid, widely distributed in southern Chubut and Santa Cruz Provinces (Cei, 1975). In addition to the nominate form, two other localized forms of this group have been discovered (Cei and Scolaro, 1981, 1983). Paying attention to their morphological similarities with *L. kingi kingi*, and pointing out the quite evident condition of allopatry in both cases, the authors described *L. kingi somuncurae* and *L. kingi baguali* as subspecies, from the Somuncurá plateau of Río Negro, and the Sierra Bagual, Santa Cruz, respectively. However, their peculiar physiognomy and the specialized conditions of the habitats justified additional research on morphological and evolutionary relationships of these still poorly known tropidurine lizards. We here assess the reciprocal position of the members of the *L. kingi* complex by means of multivariate analysis of their morphometric and exosomatic characters.

Specimens used in this study were collected on

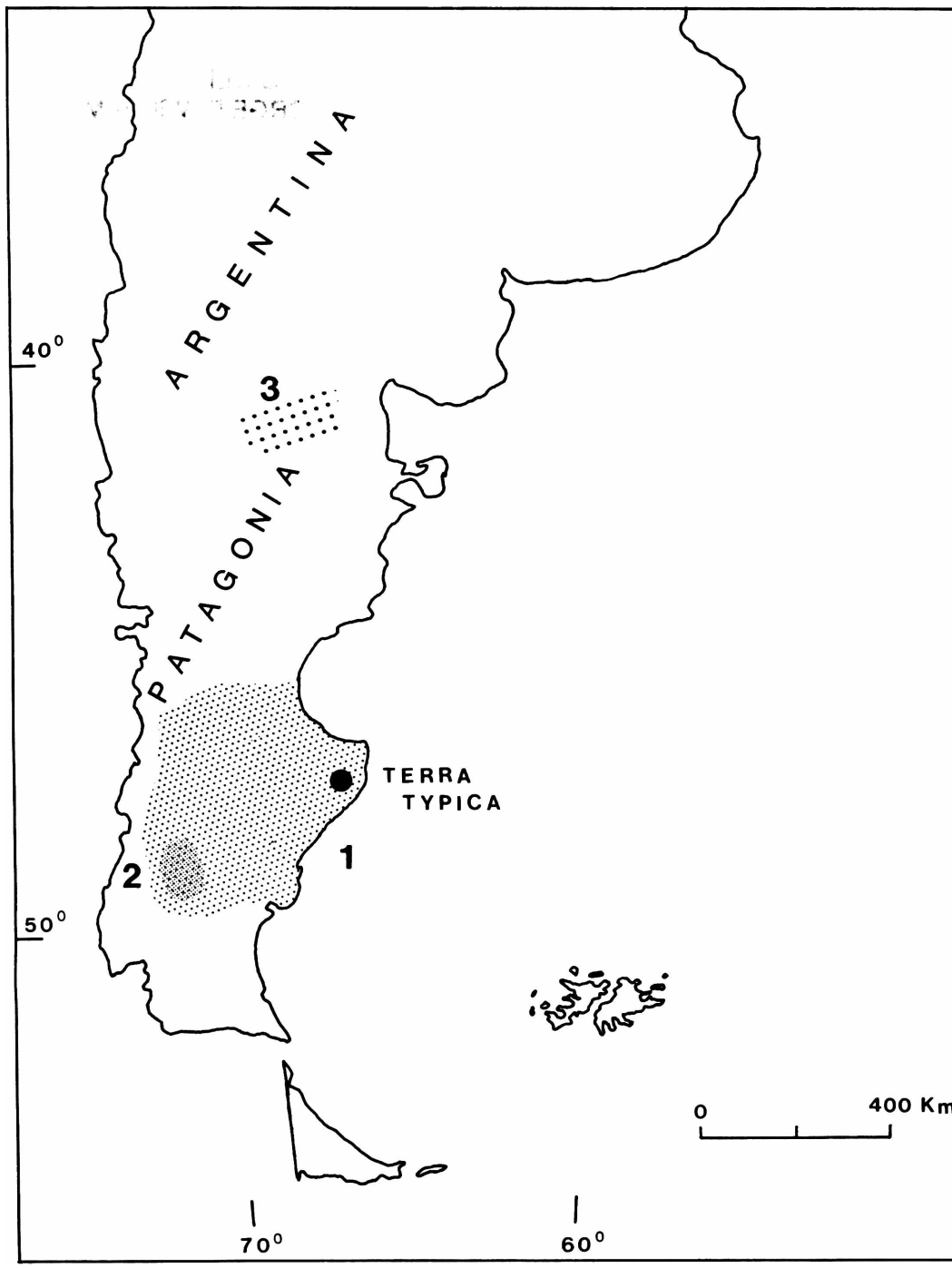
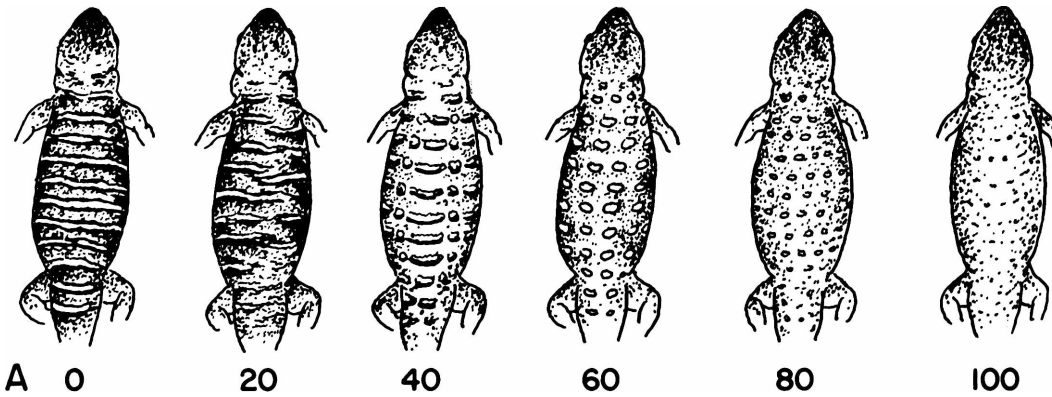


FIG. 1. Distribution map of the three populations: 1. *Liolaemus kingi kingi*, 2. *L. kingi baguali* and 3. *L. kingi somuncurae*.



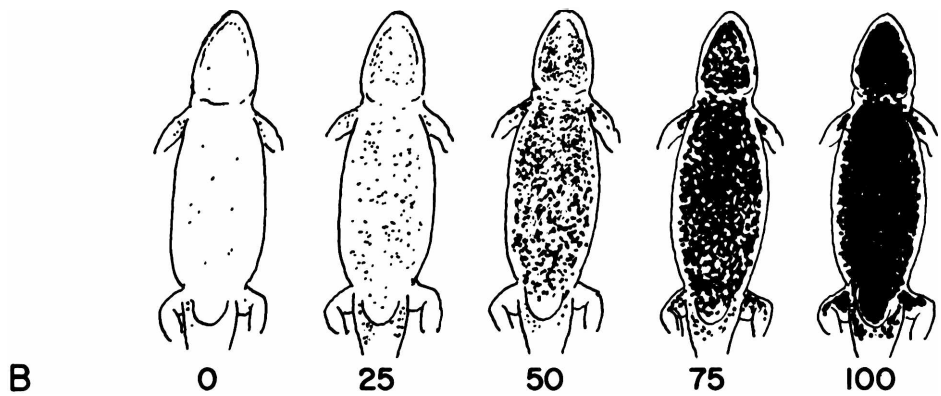


FIG. 2. Arbitrary scale of discontinuous variables referable to the dorsal stripe pattern (A) and to the ventral pigmentation (B), in *Liolaemus kingi* group. A: 0—Regular transverse light stripes; 20—Less regular, often broken light stripes; 40—Alternate, whitish streak and dot bands; 60—Transverse whitish dot lines; 80—Transverse whitish points, not too evident; 100—Almost indistinguishable transverse whitish points. (0: typical *L. kingi baguali* pattern; 100: typical *L. kingi somuncurae* pattern). B: 0—Very scarce chromatophores; 25—More evident scattered chromatophores; 50—Darker, often marble, obscure pigmentation; 75—Very dark, almost melanic, ventral pigmentation; 100—Melanic belly. (100: typical of *L. kingi baguali*).

many field trips in the Patagonian region of Argentina through 1980–1985 (Fig. 1). The 59 individuals assembled represent: *L. kingi somuncurae* (N = 14) from the volcanic Somuncurá plateau; *L. kingi baguali* (N = 17) from Sierra Bagual, Santa Cruz Province; and *L. kingi kingi* (N = 28) from Fitz Roy, Deseado, Meseta Central, Perito Moreno, Tuco-Tuco and Gregores, all localities of the Santa Cruz Province (from 47° to 49° South lat.). The specimens belong to the herpetological collections of the MZUF (Museo Zoologico Universitá di Firenze, Italy), KU (Museum of Natural History, University of Kansas), MLP (Museo de la Plata, Argentina) and JMC-DC (J. M. Cei-Diagnostic Collection).

All morphometric measurements were taken on adult specimens, whose maturity was determined by dissection. Continuous and discontinuous variables were selected in accordance with the previous descriptions of the above mentioned taxa (Cei, 1975; Cei and Scolaro, 1981, 1983). A numerical evaluation of chromatic patterns in the established groups was added to the statistical treatment with discontinuous variables. These variables, arranged according to an arbitrary numerical scale, applied by careful comparative observations, are summarized in Fig. 2. They are "dorsal stripe pattern" and "ventral pigmentation," referring to the number, shape and size of light, white or yellow, dorsal bands, and to the relative chromatophore density on throat and venter.

All the data were treated by means of two discriminant analyses (Foucart's method: 1982). Initially, 14 continuous and discontinuous variables were used. From these, a set of 9 significant variables were selected, whose further analysis are reported in this

TABLE 1. Comparative mensural characters in *L. kingi* subspecies. Values represent mean and standard deviation (SD).

Variables	*Liolaemus kingi somuncurae* (N = 14)	*Liolaemus kingi baguali* (N = 17)	*Liolaemus kingi kingi* (N = 28)
Head width (mm)	13.23 (1.08)	13.86 (1.20)	13.91 (1.87)
Hind limb length (mm)	39.06 (2.56)	41.12 (2.62)	38.42 (4.39)
Fore limb length (mm)	24.39 (2.02)	25.42 (1.93)	23.47 (2.20)
Axilla-groin length (mm)	38.01 (4.52)	38.99 (4.45)	40.12 (4.34)
Fourth toe lamellae	24.50 (2.19)	24.65 (1.45)	23.39 (2.61)
Scale number around midbody	79.14 (3.02)	81.12 (2.87)	80.11 (5.07)
Supralabial scale number	8.50 (0.50)	8.18 (0.62)	8.75 (0.78)
Dorsal stripe pattern	90.00 (14.64)	20.00 (5.94)	36.43 (7.66)
Ventral pigmentation (%)	53.57 (8.75)	95.59 (9.53)	52.68 (22.50)

paper. The considered variables, besides "dorsal stripe pattern" and "ventral pigmentation," are: "head width," "hind limb length," "fore limb length," "axilla-groin length," "fourth toe lamellae," "scale number around midbody" and "supralabial scale number." When the groups were compared, the means of each variable were tested in accordance with their type distribution (*F* Snedecor test). In the case of Gaussian normal distribution, the *t* Student test was applied; in no Gaussian distribution the "*U*" Mann-Whitney test was used.

A first discriminant analysis provided the association of the variables to the two main canonic axes obtained for the 3 subspecific groups considered. The second discriminant analysis yielded similar discrimination between groups, and a similar percentage of well classified cases was again obtained (Table 1).

The discriminant analysis supports the correlation matrix between variables (Table 2) and shows two canonic axes. The canonic axis I absorbs 57% of the total variance, and the canonic axis II the remaining 43%. The canonic axis I associates, with the most significance, the variables "dorsal stripe pattern" (positively), and "scale number around midbody" (negatively). Such an axis allows separation of *L. kingi somuncurae* from the remaining groups by a major expression of the former variable ($P < 0.001$, *t* Student test) and a minor expression of the latter ($P < 0.05$, "*U*" Mann-Whitney test).

The canonic axis II associates, with the highest significance, the following variables: "fore limb length," "ventral pigmentation" and "fourth toe lamellae" (all positively), and "supralabial scale number" (negatively). This axis allows separation of *L. kingi baguali* from the other forms. Moreover, the canonic axis II strengthens the difference between *L. kingi baguali* and *L. kingi kingi* by means of the following variables with a major expression in the former taxon: "fore limb length" ($P < 0.001$, "*U*" Mann-Whitney test), "ventral pigmentation" ($P < 0.001$, *t* Student test), and "fourth toe lamellae" ($P < 0.05$, "*U*" Mann-Whitney test). On the other hand, the variable "supralabial scale num-

TABLE 2. Correlation (*r*) matrix between variables of Table 1.

Variables	Hind limb length	Fore limb length	Axilla-groin length	Fourth toe lamellae	Scale number around midbody	Supralabial scale number	Dorsal stripe pattern	Ventral pigmentation
Head width	0.78 ***	0.62 ***	0.37 **	0.27 *	0.27 *	0.18	−0.13	0.01
Hind limb length		0.77 ***	0.31 *	0.40 **	0.32 *	0.05	−0.08	0.14
Fore limb length			0.21	0.36 **	0.31 *	0.06	−0.06	0.18
Axilla-groin length				0.03	0.14	0.08	−0.17	−0.06
Fourth toe lamellae					0.23	0.01	0.06	−0.12
Scale number around midbody						−0.18	−0.18	0.04
Supralabial scale number							0.05	−0.36 **
Dorsal stripe pattern								−0.42 ***

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

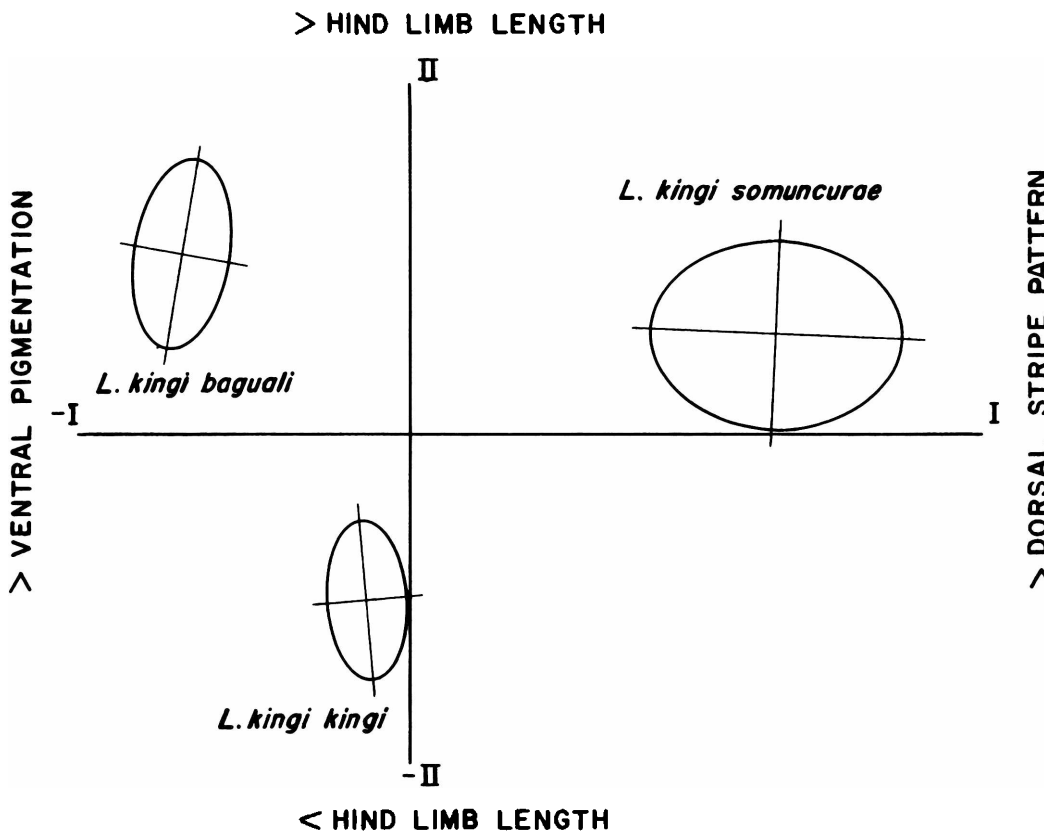


FIG. 3. Ellipses of equiprobability for all the cases ($P < 0.01$).

ber" exhibits a minor expression in *L. kingi baguali* ($P < 0.01$, "*U*" Mann-Whitney test). If the means of the remaining variables are compared, *L. kingi somuncurae* versus *L. kingi kingi* shows a major expression for the variable "fore limb length" ($P < 0.05$, "*U*" Mann-Whitney test). However, *L. kingi somuncurae* versus *L. kingi baguali* shows a minor expression for the variables "hind limb length" ($P < 0.05$, "*U*" Mann-Whitney test) and "ventral pigmentation" ($P < 0.001$, "*U*" Mann-Whitney test). Comparing *L. kingi baguali* and *L. kingi kingi*, a major expression of the variable "hind limb length" ($P < 0.05$, *t* Student test) and a minor expression of "dorsal stripe pattern" ($P < 0.001$, "*U*" Mann-Whitney test) are evident for the former taxon.

Discriminant analysis of individual specimens resulted in a very high percentage of correct classification (98.31%). Ellipses of equiprobability ($P < 0.001$: Sokal and Rohlf, 1979) for all specimens revealed no overlap between the considered groups (Fig. 3). A major distance between ellipse centroids was shown in comparison of *L. kingi somuncurae* and *L. kingi baguali*, whereas *L. kingi kingi* appeared to be nearer and approximately equidistant from both these forms.

The reported results stress a noticeable distance between all the presently known tropidurine lizards of the *Liolaemus kingi* complex, as suggested by the clear-cut separation of the population groups assembled by the respective ellipses of equiprobability. The major difference is shown by *L. kingi somuncurae* versus *L. kingi baguali*, conforming with the endemism of both forms at the extreme boundaries of the whole distribution area of the complex (Fig. 1). The nominate form is approximately equidistant from the others, but slightly nearer *L. kingi baguali* than *L. kingi somuncurae*. While a true allopatric condition, and an impressive latitudinal gap, can be pointed out for *L. kingi somuncurae* and *L. kingi kingi*, the Sierra Bagual range, home of *L. kingi baguali*, appears totally included within the very extensive area of this latter. It implies some mechanisms of topographic and ecological isolation, making gene flow difficult between the specialized basaltic rock inhabitant *L. kingi baguali*, and the widespread and ecologically more opportunistic *L. kingi kingi*, found in very different environments, even sandy shores.

Results of the present multivariate analysis, together with the distribution patterns, could suggest a probable high degree of evolutionary divergence, supported in the case of *L. kingi somuncurae* by a relatively long geological period of isolation, strengthened by physiographic barriers. In the case of *L. kingi baguali*, environmental factors may account for its morphological and perhaps genetic separation from

L. kingi kingi, in spite of possible but not proved sympatry suggested by the close approximation of their distributional boundaries. Thus, because of the allopatry of these taxa, so far as now known, we prefer for the moment not to propose nomenclatural changes, in spite of the significance of the discriminant analysis, which could justify postulation of specific status either for *L. kingi baguali* or *L. kingi somuncurae*. At any rate, a condition of "incipient species," sensu Mayr (1963), may be reasonably envisioned for these lizards.

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